Quark Matter in Neutron Stars

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The enormous gravitational pull that binds neutron stars compresses most of their matter to densities that are up to an order of magnitude higher than the mass density of atomic nuclei, 2.5×10^{14} g/cm^3. This provides a high pressure environment in which numerous subatomic particle processes, ranging from the generation of new baryonic particles $(\Sigma, \Lambda, \Xi, \Delta)$ to quark deconfinement to the formation of (π^- or K^-) Boson condensates and H (dibaryon) matter, are expected to compete with one another and novel phases of matter, like the quark-gluon plasma state being sought at the most powerful terrestrial particle colliders, could exist [1].

A sample composition of neutron star matter accounting for quark decofinement is shown in Fig. 1. Whether or not quark deconfinement ineed occurs in neutron stars is hard, if not impossible, to tell from their static properties. This may be quite different when diagnosing the properties of rotating neutron stars, as shown in [1, 2]. The diagnosis hinges on the changes in density. As a rotating neutron star gradually spins down, it becomes more dense. If the density crosses the critical threshold so that hadronic matter transforms into quark matter, which is much more compressible than hadronic matter, the star will compress under its own gravity, which strongly alters its moment of inertia. As a consequence, neutron stars gradually converting hadronic matter into quark matter change their rotational speed. They may even speed up for some time before slowing down again, depending on how sensitively the size of the quark matter core varies with frequency. This can cause significant anomalies in the braking index of a neutron star. Hence by monitoring the radio pulses that emanate from rotating neutron stars, astronomers might be able to watch them turning into the hypothetical quark-gluon plasma state, provided the anomaly is not obscured by other physical dense-matter processes competing with deconfinement. If the telltale signal – an anomaly in the star's braking index – is detected, physicists would have their first glimpse on the kind of matter that filled the Universe milliseconds after the Big Bang.

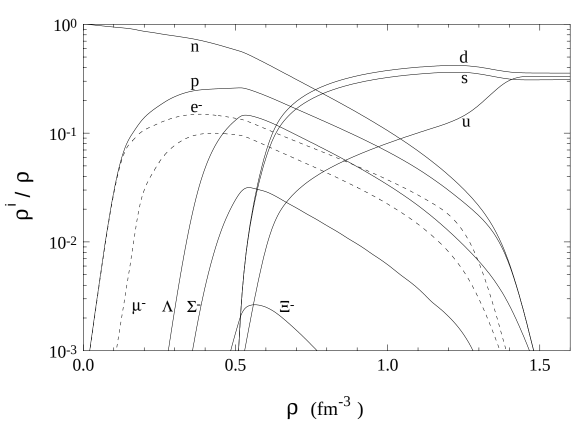

Figure 1: Sample composition of neutron star matter accounting for quark deconfinement.

The observation of a pulsar with an anomalously large braking index would help to clarify how quark matter behaves and give a boost to theories about the early Universe as well as laboratory searches for the production of quark matter in heavy-ion collisions.

References

[1] F. Weber; 'Pulsars as Astrophysical Laboratories for Nuclear and Particle Physics', IOP Publishing, Bristol, Great Britain, 1999

[2] F. Weber; J. Phys. G: Nucl. Part. Phys. 25 (1999) R195